

UNCLASSIFIED

AD NUMBER

AD152954

CLASSIFICATION CHANGES

TO: UNCLASSIFIED

FROM: CONFIDENTIAL

LIMITATION CHANGES

TO:
Approved for public release; distribution is unlimited.

FROM:
Distribution authorized to U.S. Gov't. agencies and their contractors;
Administrative/Operational Use; OCT 1957. Other requests shall be referred to Ballistic Research Labs., Aberdeen Proving Ground, MD.

AUTHORITY

BRL ltr 22 Apr 1981 ; BRL ltr 22 Apr 1981

THIS PAGE IS UNCLASSIFIED

THIS REPORT HAS BEEN DELIMITED
AND CLEANED FOR PUBLIC RELEASE
UNDER DOD DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE,
DISTRIBUTION UNLIMITED.

UNCLASSIFIED

AD _____

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



DOWNGRADED AT 3 YEAR INTERVALS:
DECLASSIFIED AFTER 12 YEARS
DOD DIR 5200.10

UNCLASSIFIED

**A
D 152954**

Armed Services Technical Information Agency

**ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA**

**FOR
MICRO-CARD
CONTROL ONLY**

1 OF 1

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE OR SELL ANY PATENTED INVENTION THEREOF IN ANY WAY RE RELATED THERETO.

CONFIDENTIAL

AD No. 152954
ASTIA FILE COPY

0052

BRL

FC

MEMORANDUM REPORT No. 1101

OCTOBER 1957

**Drag And Stability Properties
Of A Redstone Warhead Model (U)**

L. C. MacALLISTER

DEPARTMENT OF THE ARMY PROJECT No. 5803-03-001
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TR3-0106



BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

CONFIDENTIAL

5811

570

FEB 20 1958

BEST

AVAILABLE

COPY

CONFIDENTIAL

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1101

OCTOBER 1957

DRAG AND STABILITY PROPERTIES OF A REDSTONE WARHEAD MODEL (U)

L. C. MacAllister

Requests for additional copies of this report
will be made direct to ASTIA.

Reproduction of this document in whole or in part is prohibited
except with permission of the issuing office; however, ASTIA is
authorized to reproduce this document for U. S. Government purposes.

Department of the Army Project No. 5B03-03-001
Ordnance Research and Development Project No. TB3-0108

ABERDEEN PROVING GROUND, MARYLAND

CONFIDENTIAL

58AA

570

CONFIDENTIAL

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1101

LCMacAllister/iw
Aberdeen Proving Ground, Md.
October 1957

DRAG AND STABILITY PROPERTIES OF A REDSTONE WARHEAD MODEL (U)

ABSTRACT

The drag and stability properties of a Redstone Warhead Model, as determined by range firings, for $0.7 < M < 3.5$ are presented.

CONFIDENTIAL

CONFIDENTIAL

SYMBOLS

C_D	Drag coefficient
C_{M_α}	Static moment derivative (per radian)
C_{N_α}	Normal force derivative (per radian)
CP_N	Center of pressure (calibers from base)
C_{m_q}	Damping derivative due to angular velocity
$C_{m_{\dot{\alpha}}}$	Damping derivative due to yawing velocity
	reference area = base area
	reference length = base diameter (d)

CONFIDENTIAL

INTRODUCTION

A version of the Redstone missile Warhead was tested in the Transonic Free Flight Range¹ of the Ballistic Research Laboratories at the request of ABMA. The current model (Fig. 1 and 2) differed from earlier models² in that the after body was a single conical section instead of a cone section and a cylinder. The models were encased in a plastic sabot (Fig. 2) and launched through the range from a smooth bored five-inch gun. Sixteen models were launched at speeds from 800 to 4000 fps and all but one model traversed the full range of instrumentation. A summary of the initial firing data and the physical measurements of the model are given in Table I.

RESULTS

The range data were processed by the usual techniques³ and the reduction and motion parameters are given in Table II. The resulting aerodynamic coefficients are given in Table III.

The drag coefficient, C_D , is shown in Figure 3. The curve shown is for zero yaw. A value of $C_{D\delta^2}$ of 2.5 per squared radians has been used to reduce the individual round values to a zero yaw value. This value of $C_{D\delta^2}$ seems adequate for the supersonic data.

The moment derivative, $C_{M\alpha}$, (for a center of mass position 2.47 calibers forward of base) is given in Figure 4. Maximum stability occurs at about $M = 0.9$ and decreases with increasing Mach number. In fact, extrapolation would give a neutral point at about $M = 6$; however, the slope of the $C_{m\alpha}$ curve may change at speeds above those tested. The normal force slope is shown in Figure 5 and the center of pressure of the normal force in Figure 6.

The damping moment derivatives, $(C_{m\dot{q}} + C_{m\dot{\alpha}})$, Figure 7, are stabilizing except at high subsonic speeds. For Mach numbers greater than about 1.1 $(C_{m\dot{q}} + C_{m\dot{\alpha}})$ is fairly constant and adequately large.

Representative shadowgraphs of the model in flight are given in Figure 8 to 16. It might be noted that even at the lowest test speed ($M \doteq 0.7$) small shock waves exist at the corner of the nose cone, hence these data do not represent a fully subsonic local flow state. Also, almost all of the variations of the model's properties, except slow trends, occur in the region from the

CONFIDENTIAL

lowest speed tested up to about $M = 1.2$ where full supersonic flow appears to be established over the body and the control vanes.

REMARKS

Normally in the processing of range data from a statically stable symmetric missile which is not spinning and has a linear force system certain equalities of the reduction parameters are preserved. Primarily these are equality in magnitude of the epicyclic rates, b_1 and b_2 . It can be noted in Table II that these equalities are not always present to within the probable accuracy of the data. Generally this can be ascribed to three causes:

1. Small size of one of the epicyclic modes, a degenerate fitting condition, i.e., rounds 2-4471 and 2-4476. These may be handled by computing the properties utilizing the equalities and the significant mode.

2. Small missile asymmetries where impossible, or impractical, to process by asymmetric reduction systems. The highest velocity rounds are most apt, mechanically, to have suffered some slight damage.

3. Nonlinearity of the aerodynamic force system. This is partially allowed for but may be the only logical reason why the data for the low Mach number rounds has inconsistent damping for the two modes.

L. C. MacAllister

L. C. MacALLISTER

CONFIDENTIAL

REFERENCES

1. Rogers, W. K., The Transonic Free Flight Range, BRL Report No. ~~889~~, 1953. AD-13 358
2. Rogers, W. K., Free Flight Tests of A Model of The "Redstone", KSSM-A-14, Warhead, BRIM 885, 1955. AD-69214
3. Murphy, C. H., Data Reduction for Free Flight Ranges, BRL Report 900, 1956. AD-35833 ?

CONFIDENTIAL

TABLE I
Test Conditions

Round Number	Date 1957	Mid Range Test Velocity fps	Weight lb	C. G. in. from base	Remarks
2-4431	2 March	3450	8.11		
2-4432	2 March	1280	8.08		
2-4433	2 March	830	8.10	7.413	
2-4470	18 March	1250	8.11	7.422	
2-4471	18 March	1470	8.10	7.515	
2-4472	18 March	1600	8.11	7.420	Hit fragment shield in second group
-4473	18 March	1600	8.10	7.416	
2-4474	20 March	2770	8.08	7.404	
2-4475	20 March	2430	8.09	7.412	
2-4476	20 March	3060	8.09	7.410	
2-4479	27 March	810	8.09	7.414	
2-4480	27 March	810	8.11	7.414	
2-4481	27 March	920	8.10	7.414	
2-4482	28 March	1050	8.10	7.414	
2-4483	28 March	1100	8.09	7.414	
2-4484	28 March	3990	8.10	7.413	

Average maximum diameter (20 measurements) = 3.000 ($\begin{smallmatrix} +.002 \\ -.001 \end{smallmatrix}$)

Average length (20 measurements) = 14.397 ($\begin{smallmatrix} +.006 \\ -.017 \end{smallmatrix}$ in)

Average axial mement of inertia
(2 measurements) = 6.39 lb-in²

Average transverse moment of inertia
(2 measurements) = 101.50 lb-in²

CONFIDENTIAL

TABLES II

REDUCTION AND MOTION PARAMETERS

Round Number	Mach Number	$\overline{\delta^2}$ (deg ²)	Epicyclic Yaw Rates (deg/ft)		Model Damping Rates (1/ft)		Mid-range values of yaw arms (rad)		Standard Error	
			b_1	b_2	$\lambda_1 10^3$	$\lambda_2 10^3$	K_1	K_2	Yaw Fit rad	Swerve Fit feet
2-4479	.717	11.2	-1.853	1.932	- .45	- .05	.0248	.0529	.0030	.020
2-4480	.720	9.8	-1.909	+1.897	+1.02	- .47	.0325	.0424	.0048	.041
2-4481	.814	5.9	-1.999	+2.031	+ .44	+ .32	.0303	.0292	.0029	.020
2-4482	.921	22.5	-2.198	+2.17	1.21	+1.40	.0291	.0904	.0045	.015
2-4483	.971	7.7	-2.031	+2.058	1.10	+1.57	.0210	.0394	.0040	.015
2-4470	1.110	5.3	-1.865	+1.848	1.65	+1.59	.0260	.0254	.0027	.018
2-4471	1.302	1.4	-1.449	+1.785	1.56	+3.96	.0169	.0052	.0020	.016
2-4473	1.436	15.0	-1.339	+1.371	1.18	+1.64	.0298	.0547	.0042	.031
2-4475	2.159	4.1	-1.138	+1.116	1.65	+1.46	.0244	.0212	.0016	.022
2-4474	2.465	9.4	-1.129	+1.032	1.60	+1.62	.0315	.0325	.0027	.012
2-4476	2.714	1.2	-1.061	+1.000	2.09	+1.47	.0081	.0156	.0033	.025
2-4484	3.453	5.0	-0.904	+0.904	2.29	2.29	.0238	.0216	.0058	.061

CONFIDENTIAL

TABLE III
AERODYNAMICS COEFFICIENTS

Mach Number	Reynolds Number (10^{-6})	$\bar{\delta}^2$ (deg ²)	C_D	C_{M_α} (per rad)	C_{N_α} (per rad)	C_{P_N} (from base)	$C_{M_q} + C_{M_\alpha}$	Round Number
.717	1.25	11.2	.2801	-1.668	3.79	2.03	4.1	2-4479
.722	1.26	9.8	.2801	-1.685	3.63	2.01	8.5	2-4480
.737	0		.2758					
.814	1.42	5.9	.2956	-1.890	3.06	1.85	-2.3	2-4481
.921	1.61	22.5	.3998	-2.217	3.44	1.83	-24.5	2-4482
.971	1.70	7.7	.4395	-1.939	5.14	2.09	-20.6	2-4483
1.110	1.93	5.3	.5485	-1.610	4.48	2.11	-30.2	2-4470
1.302	2.27	1.4	.5024	-1.215	<u>4.08</u>	<u>2.17</u>	<u>-59.0</u>	2-4471
1.430	2.51	15.2	.4966	-.858	3.32	2.21	-28.0	2-4473
2.159	3.73	4.1	.3845	-.601	3.46	2.30	-30.9	2-4475
2.465	4.29	9.4	.3456	-.547	3.28	2.30	-32.2	2-4474
2.714	4.68	1.2	.3163	-.504	3.86	2.34	-35.1	2-4476
3.05		0	.2872					
3.453	6.02	5.0	.2633	-.388	2.73	2.33	49.9	2-4484

Underlined values are poorly determined due to small yaw size.

CONFIDENTIAL

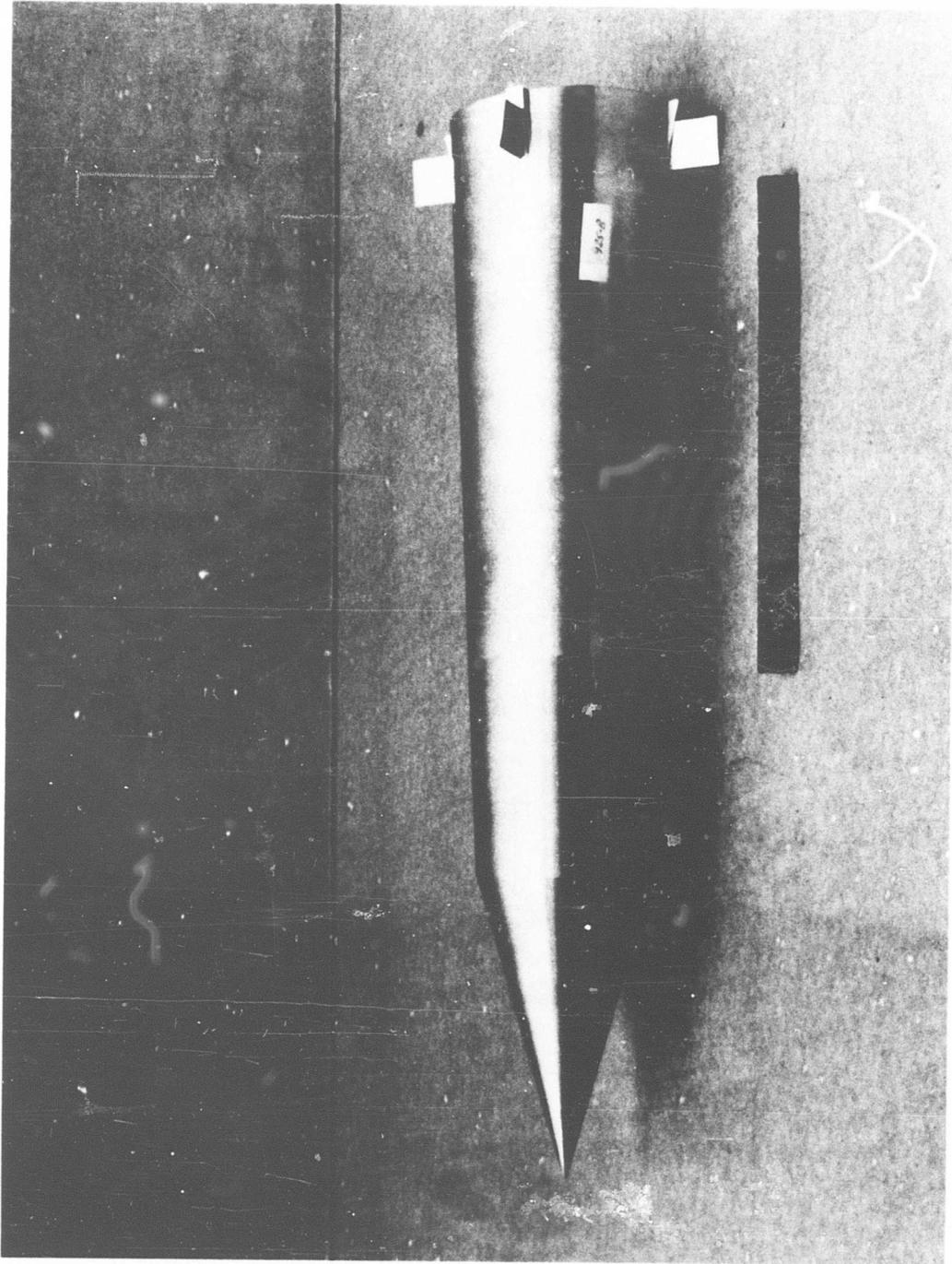
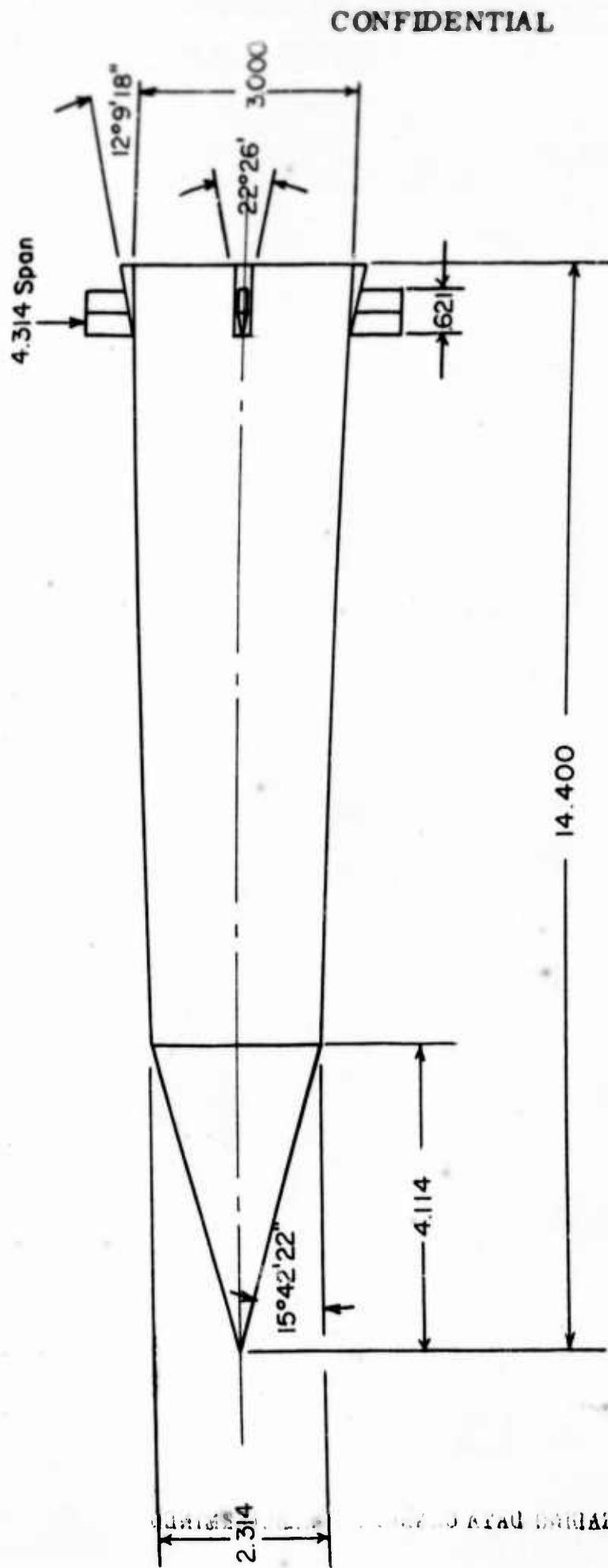


FIGURE 1 RANGE MODEL

CONFIDENTIAL

REDSTONE WARHEAD



CONFIDENTIAL

NOTE: All Dimensions are in Inches

FIGURE 10

CONFIDENTIAL

CONFIDENTIAL

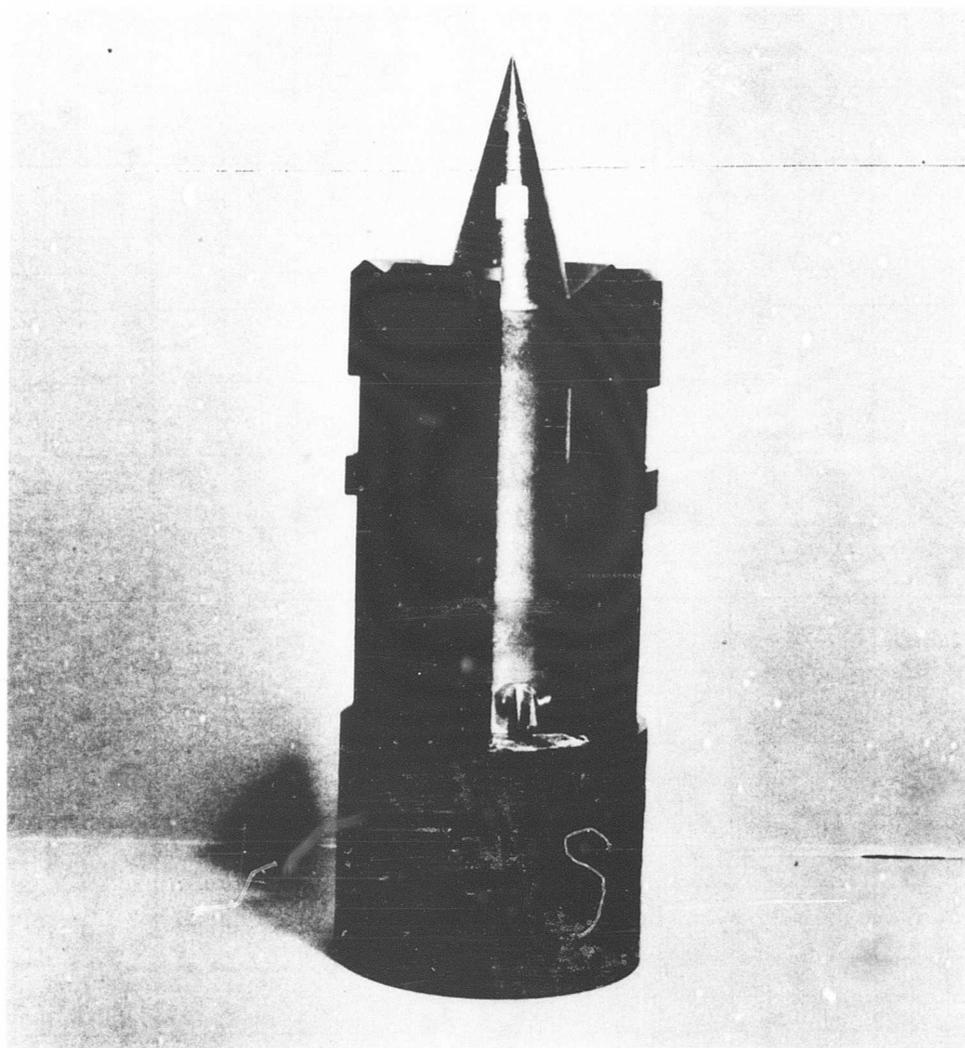


FIGURE 2 TYPICAL RANGE MODEL IN SABOT

CONFIDENTIAL

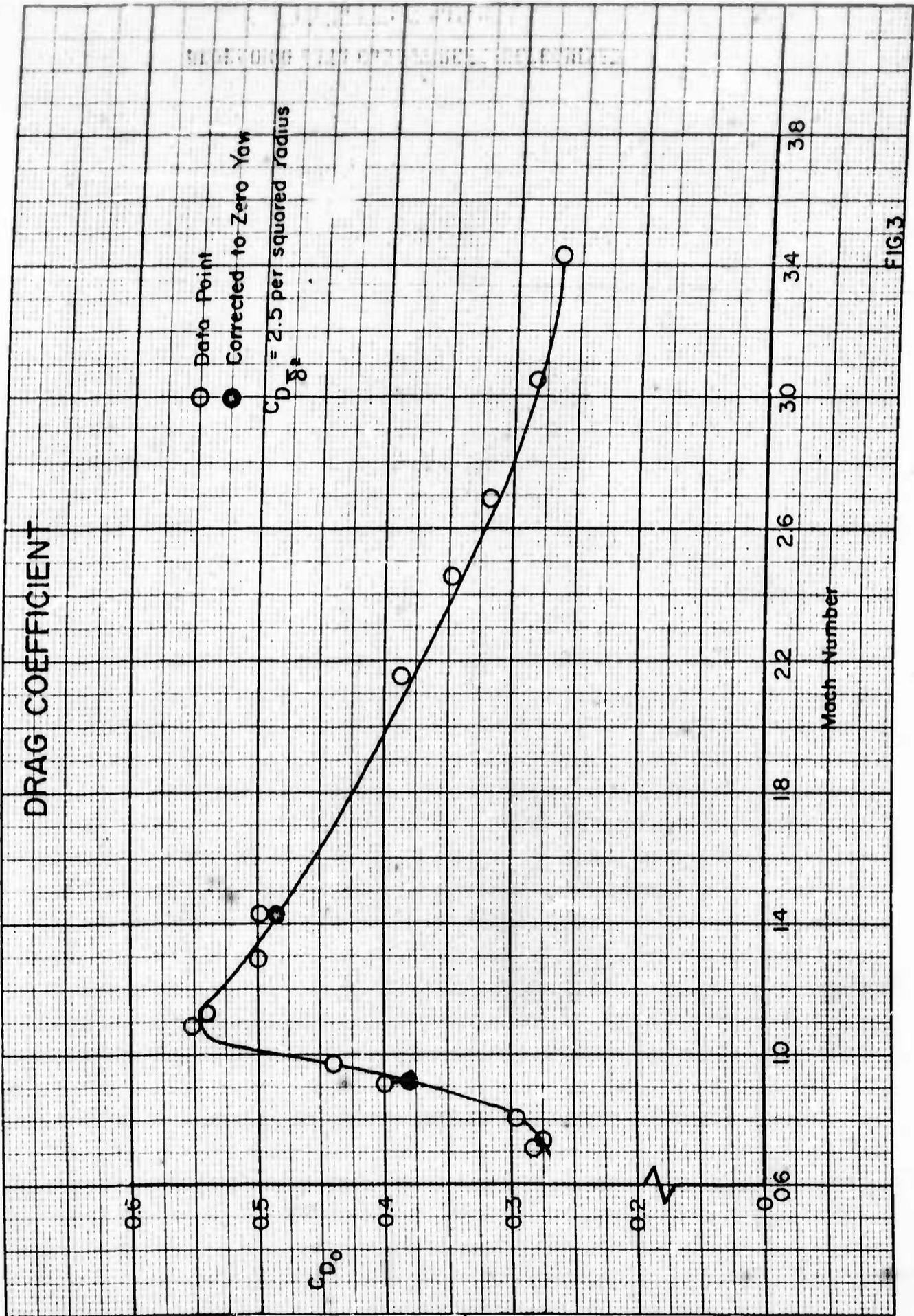


FIG. 3

CONFIDENTIAL

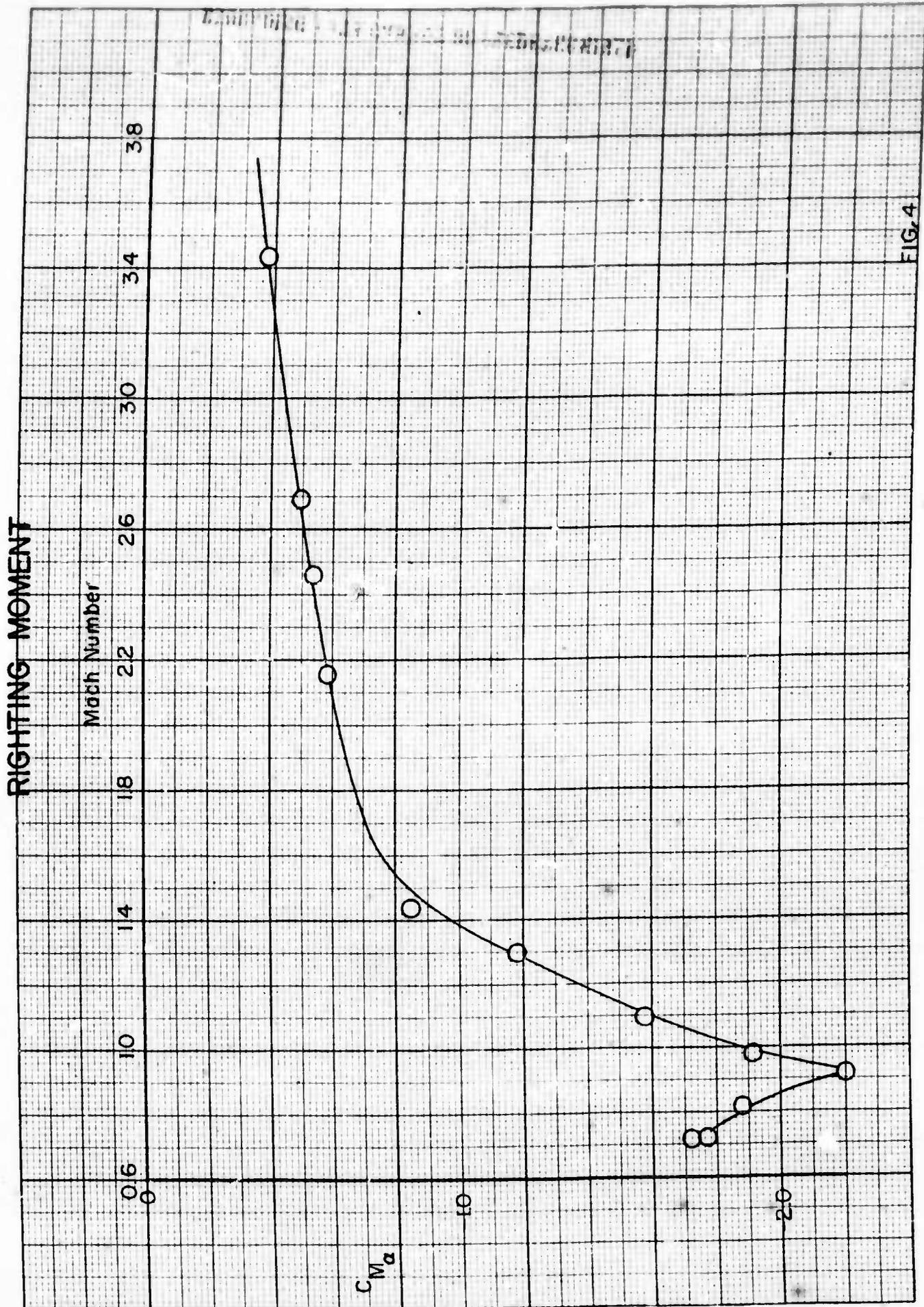


FIG. 4

CONFIDENTIAL

CONFIDENTIAL

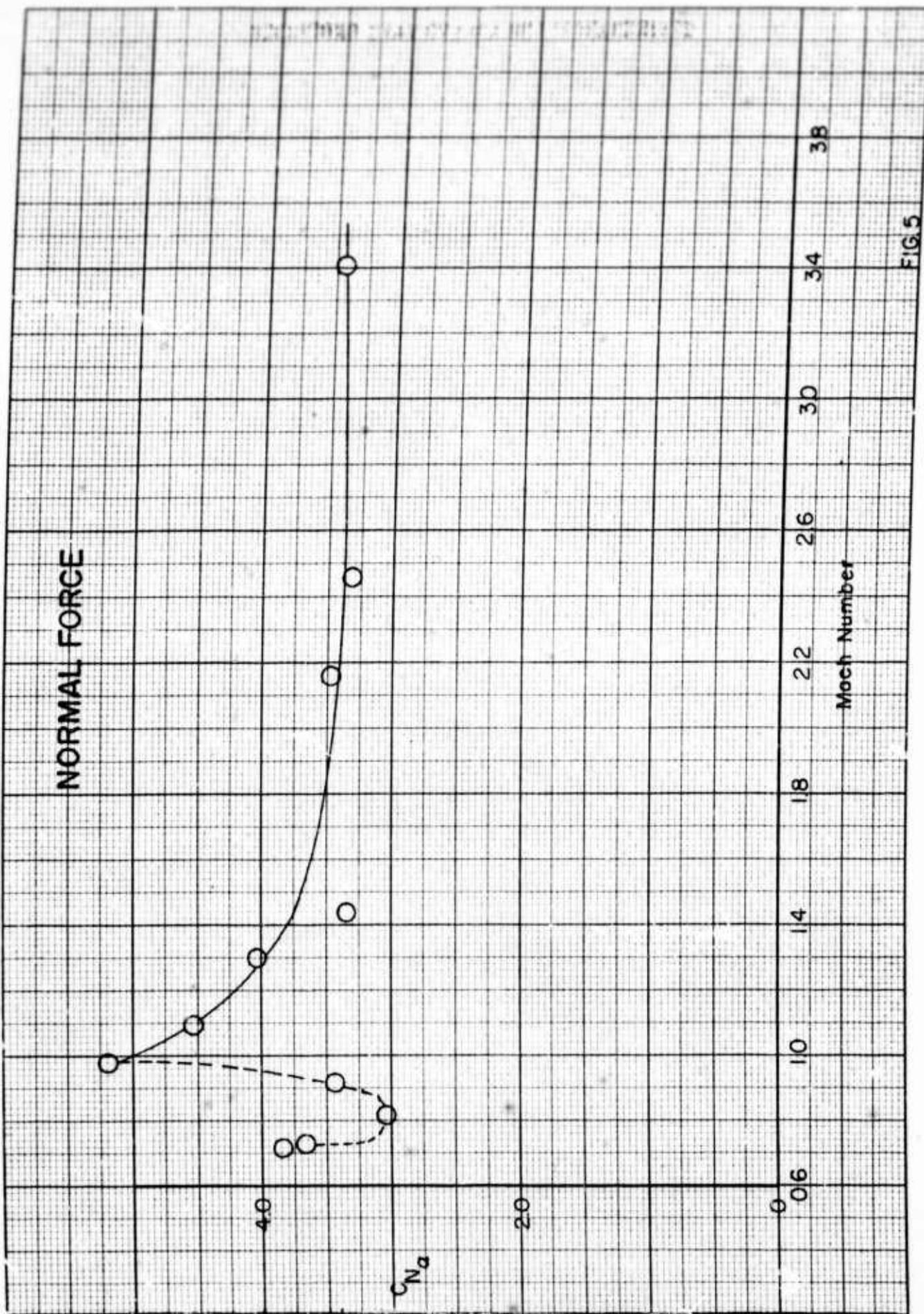


FIG. 5

CONFIDENTIAL

CONFIDENTIAL

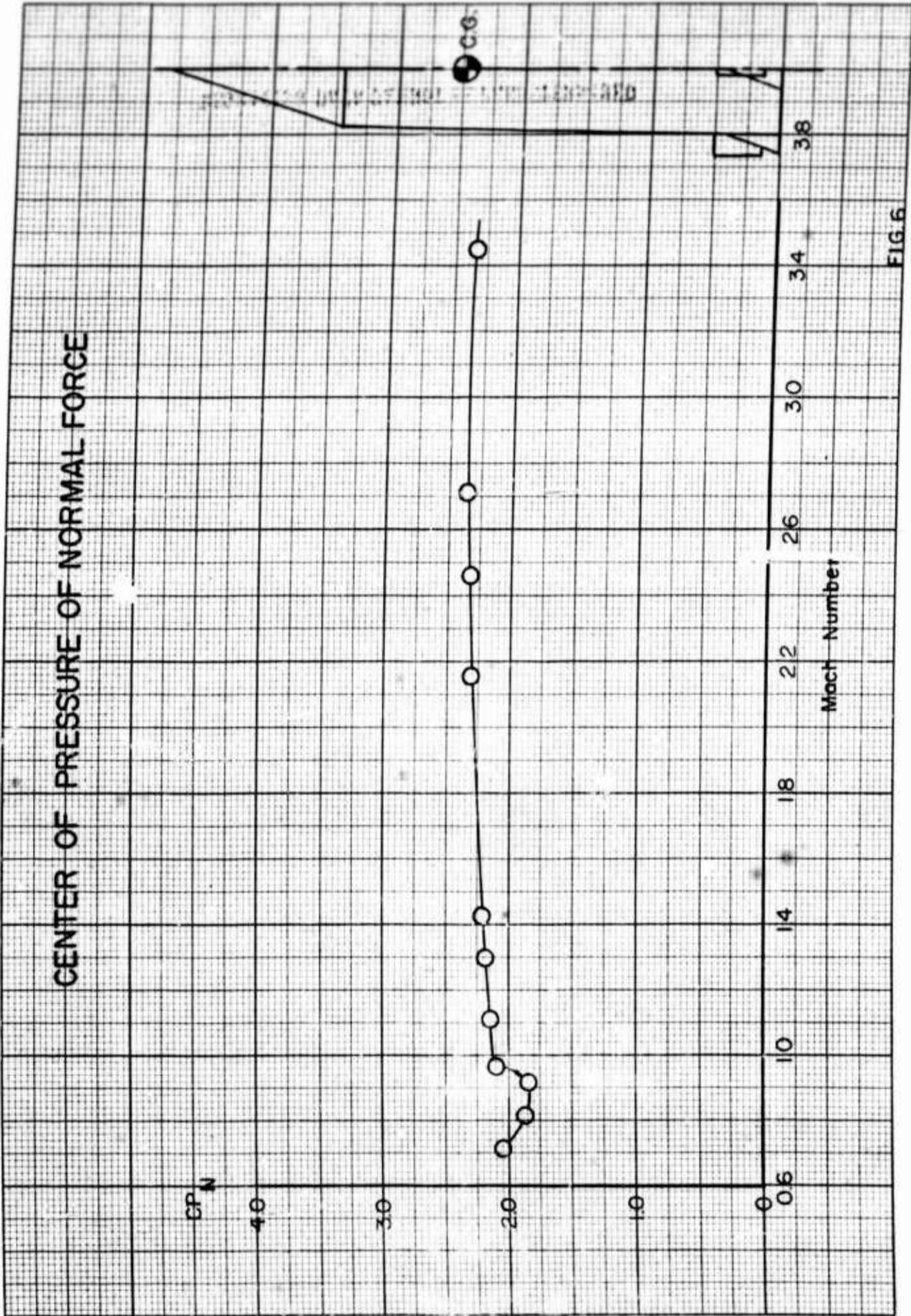


FIG. 6

CONFIDENTIAL

CONFIDENTIAL

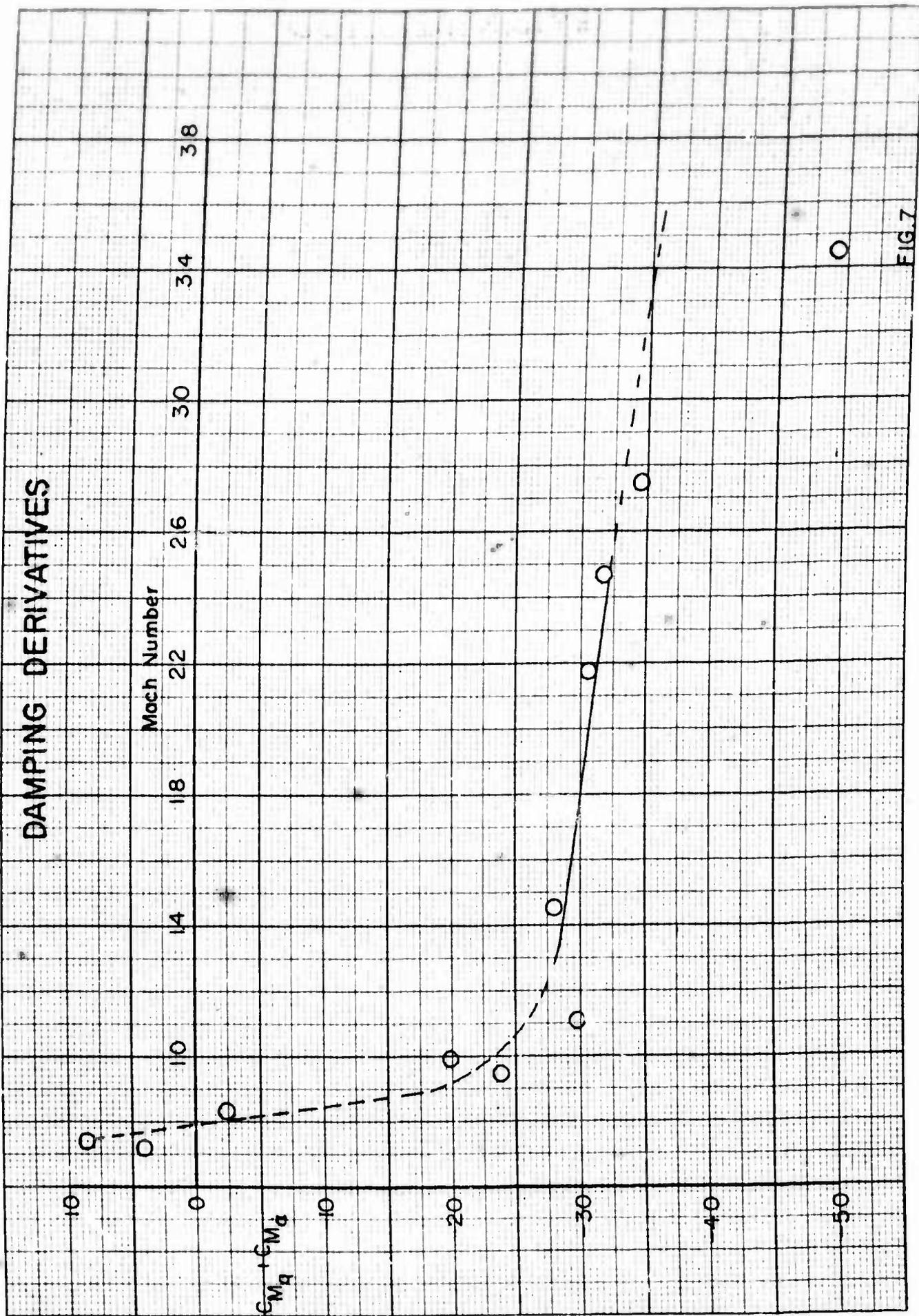


FIG. 7

CONFIDENTIAL

CONFIDENTIAL

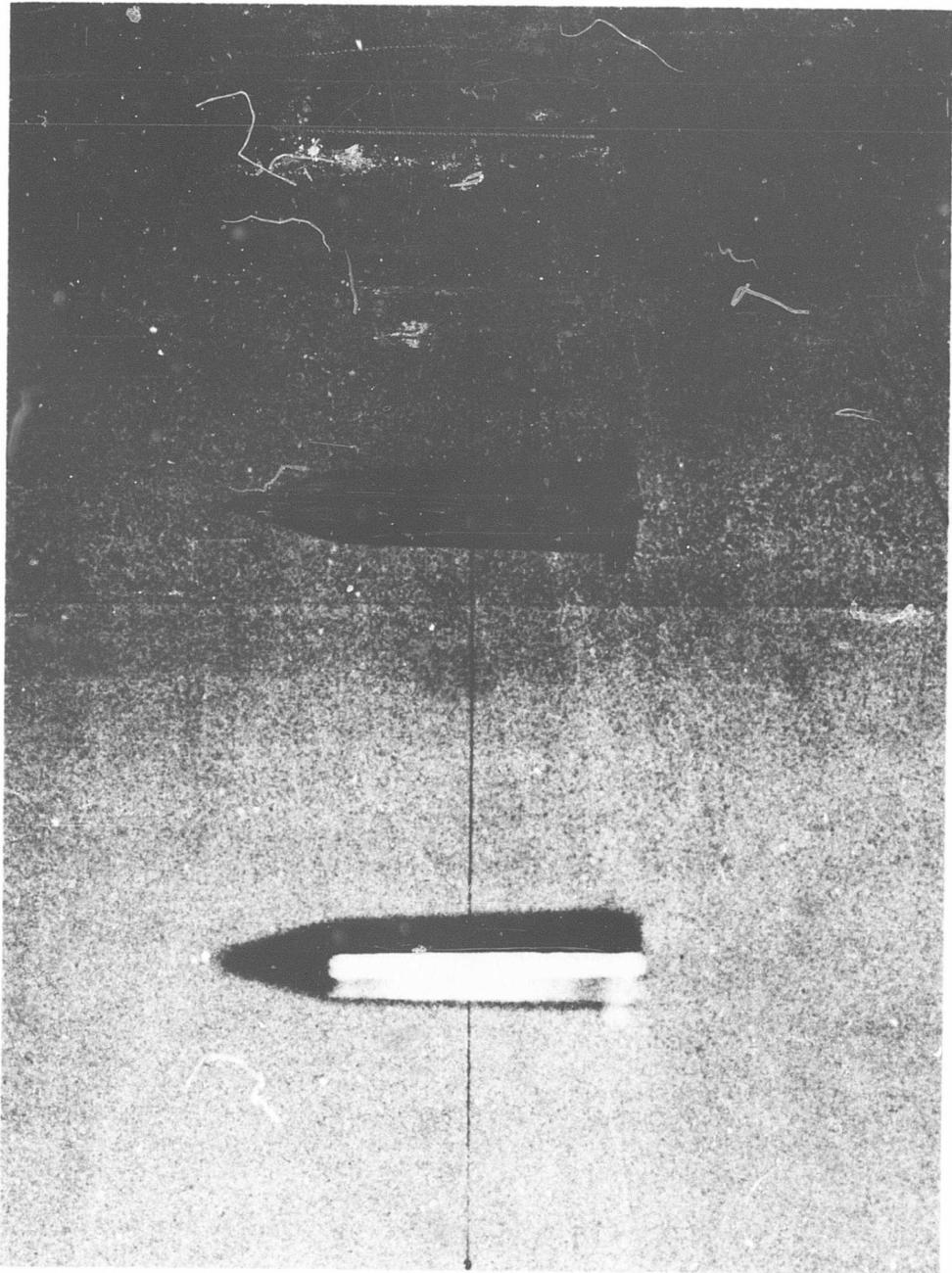


FIGURE 8 SHADOWGRAPH $M \approx 0.72$

CONFIDENTIAL

CONFIDENTIAL

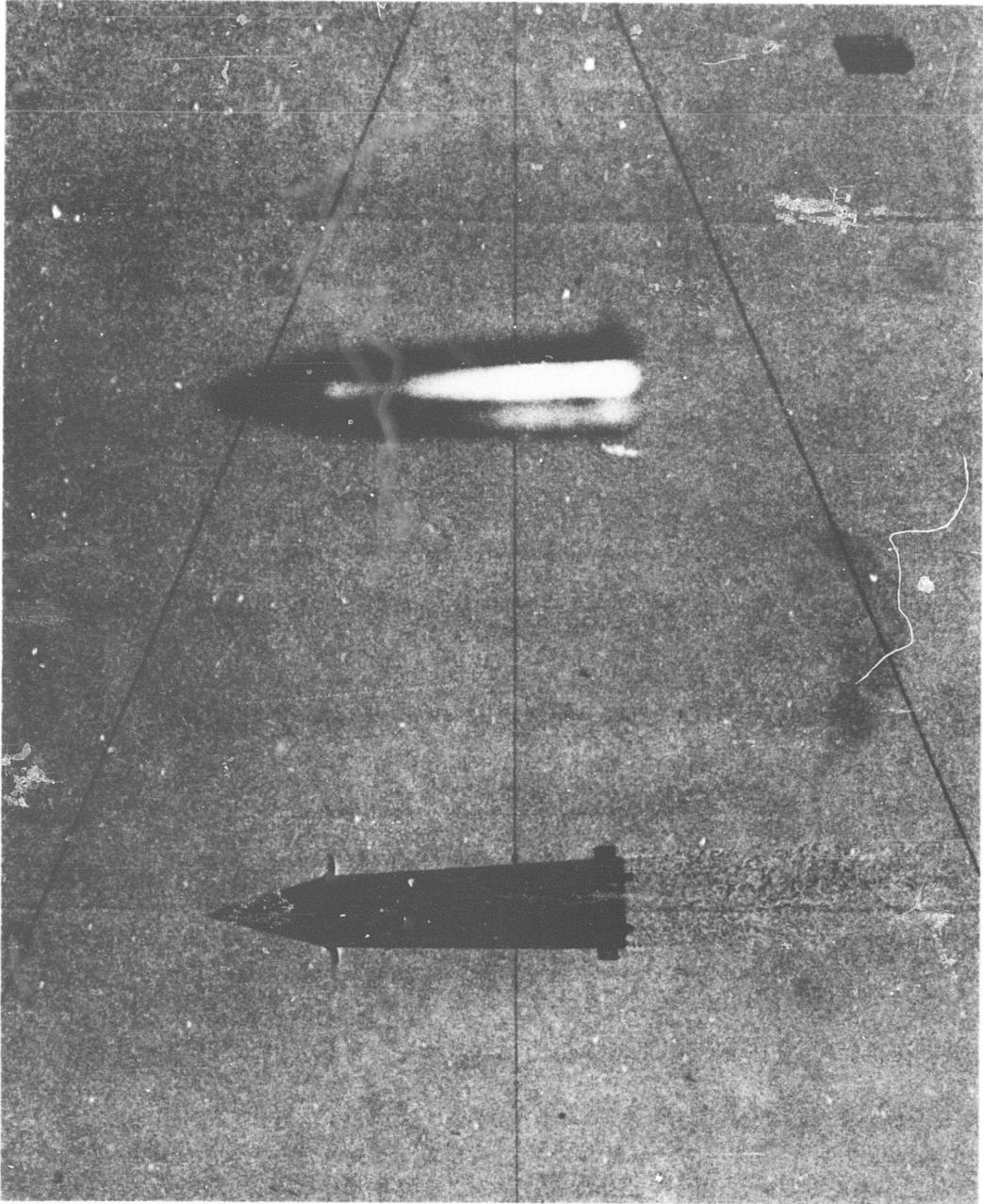


FIGURE 9 SHADOWGRAPH $M \approx 0.81$

CONFIDENTIAL

CONFIDENTIAL

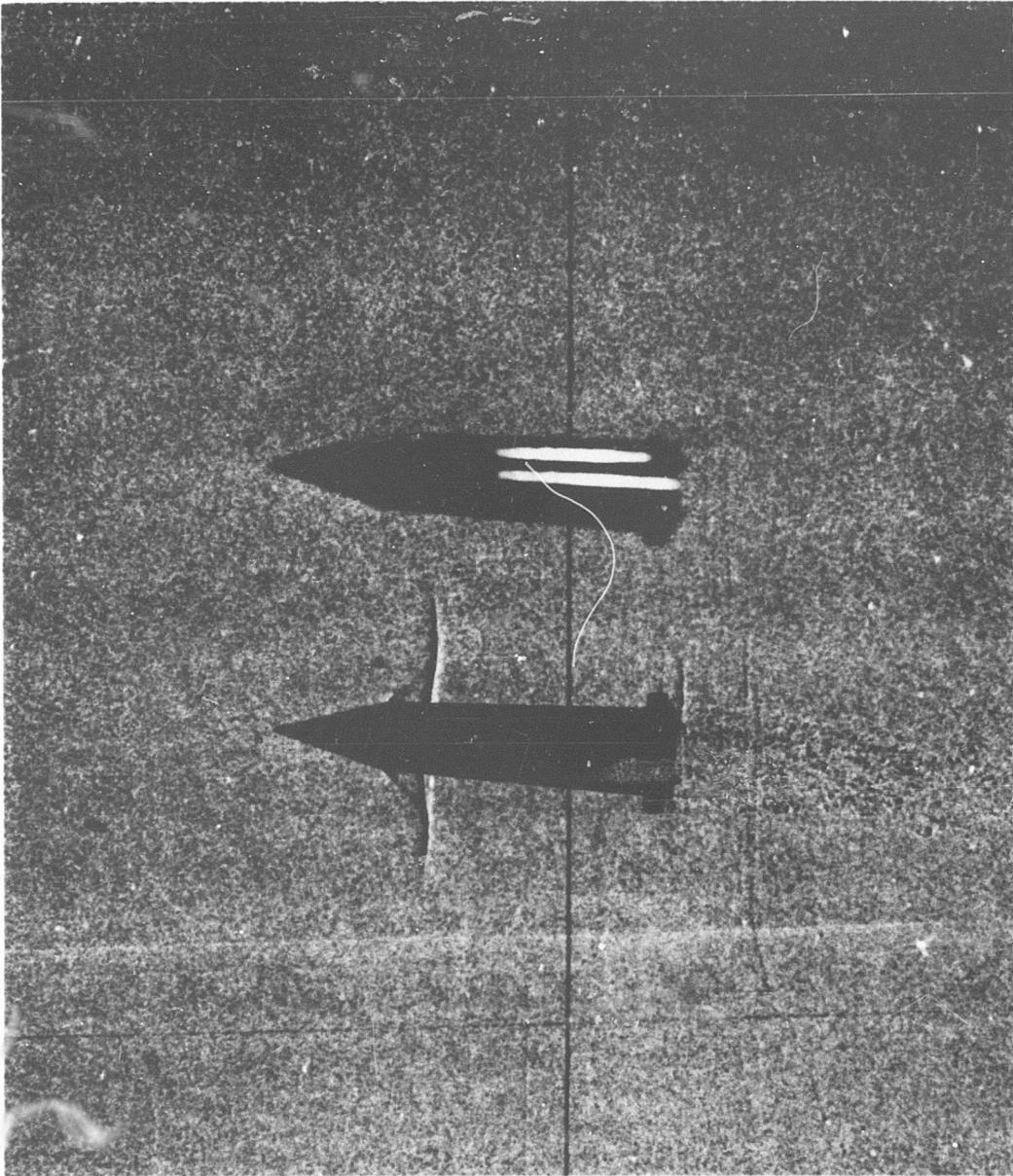


FIGURE 10 SHADOWGRAPH $M \approx 0.92$

CONFIDENTIAL

CONFIDENTIAL

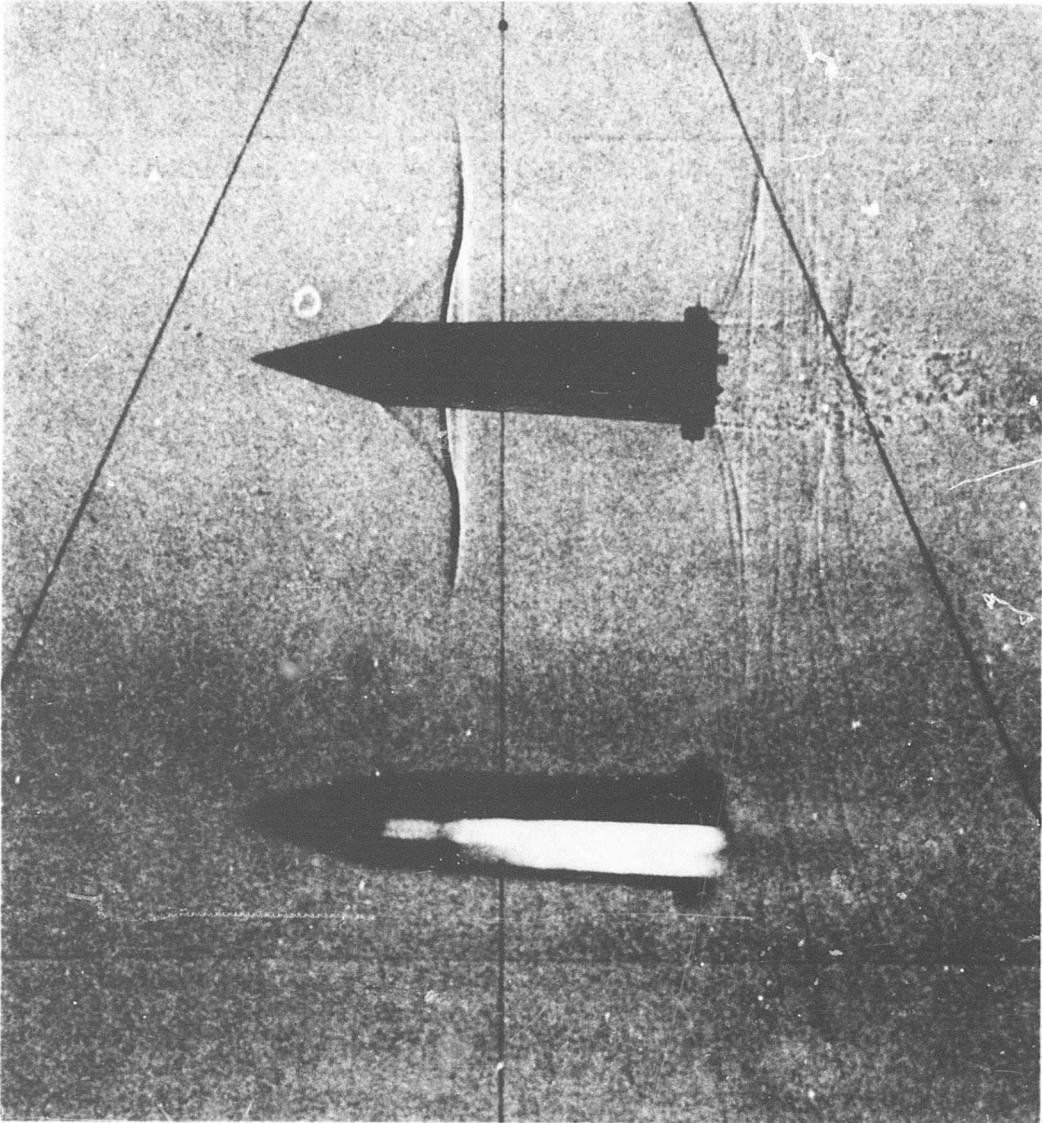


FIGURE 11 SHADOWGRAPH $M \approx 0.97$

CONFIDENTIAL

CONFIDENTIAL

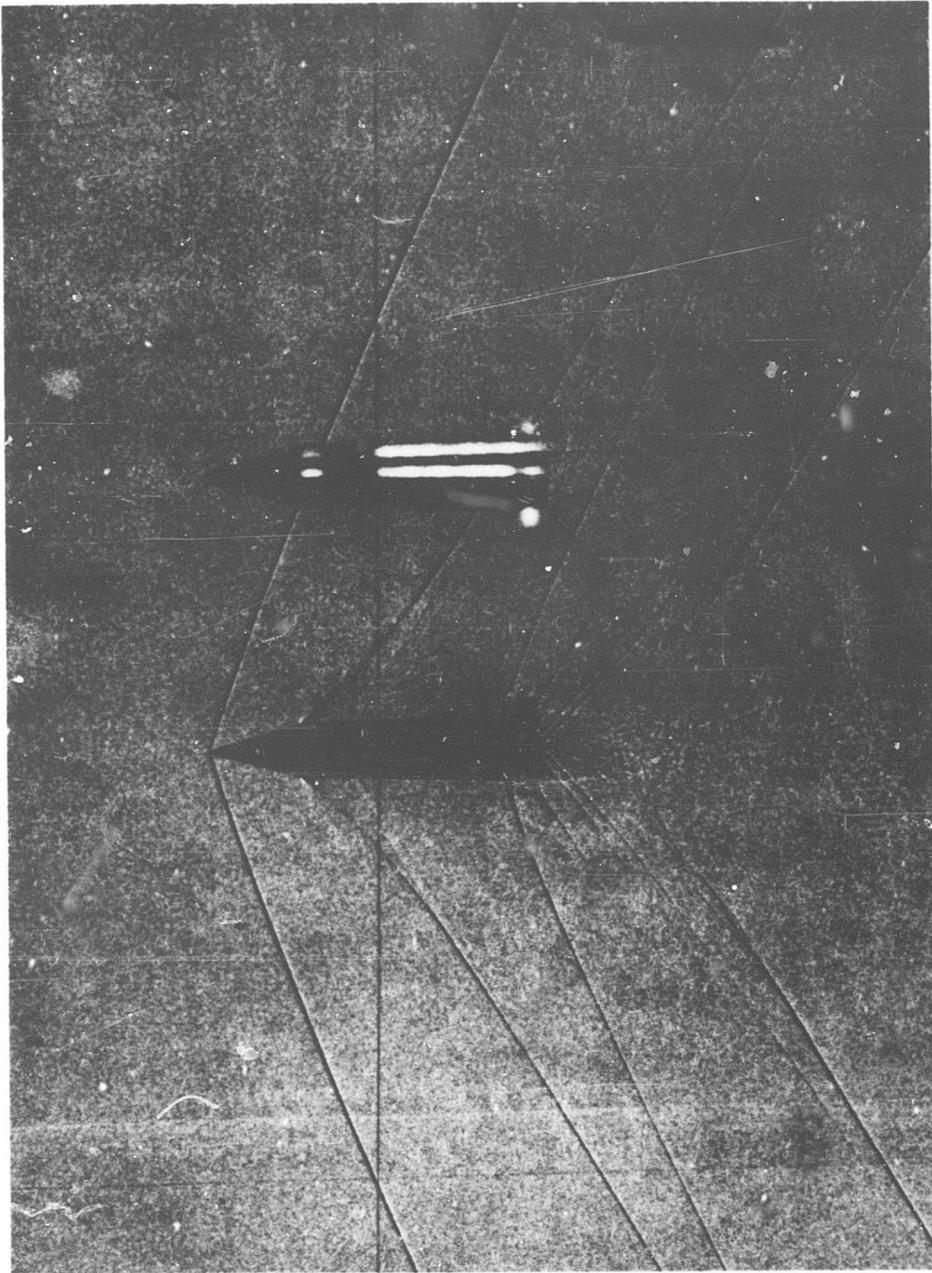


FIGURE 12 SHADOWGRAPH $M \approx 1.11$

CONFIDENTIAL

CONFIDENTIAL

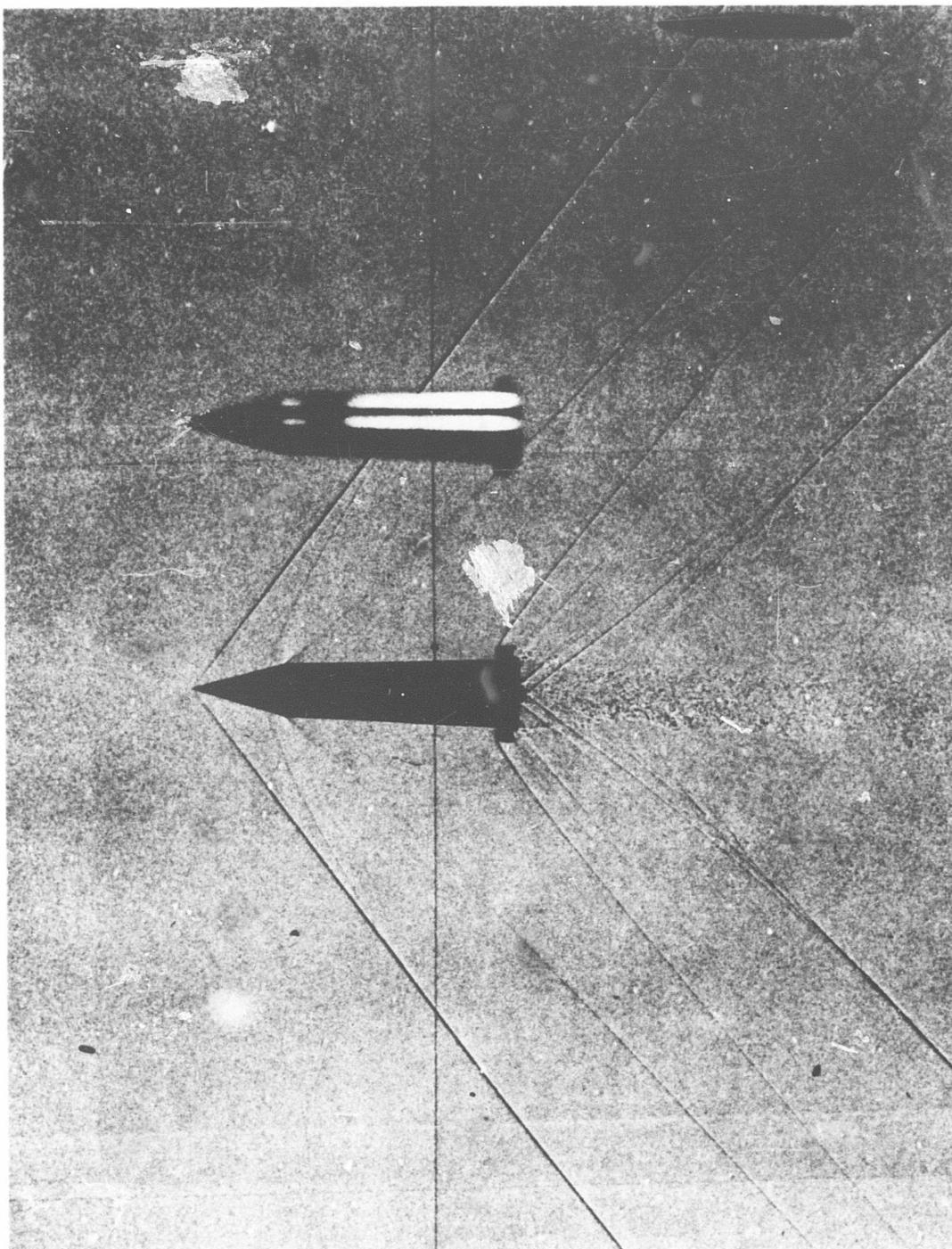


FIGURE 13 SHADOWGRAPH $M \approx L30$

CONFIDENTIAL

CONFIDENTIAL

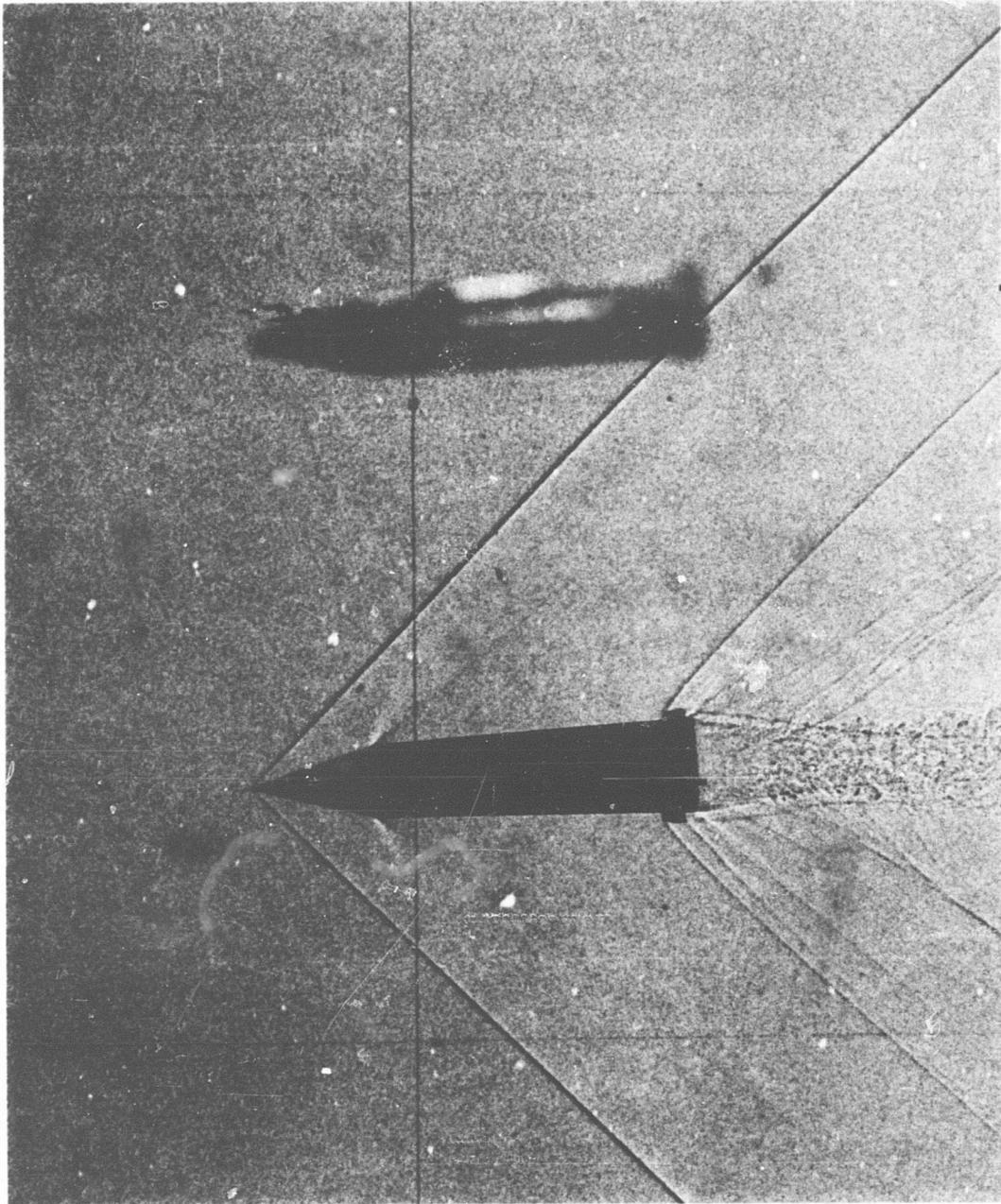


FIGURE 14 SHADOWGRAPH $M \approx 1.52$

CONFIDENTIAL

CONFIDENTIAL

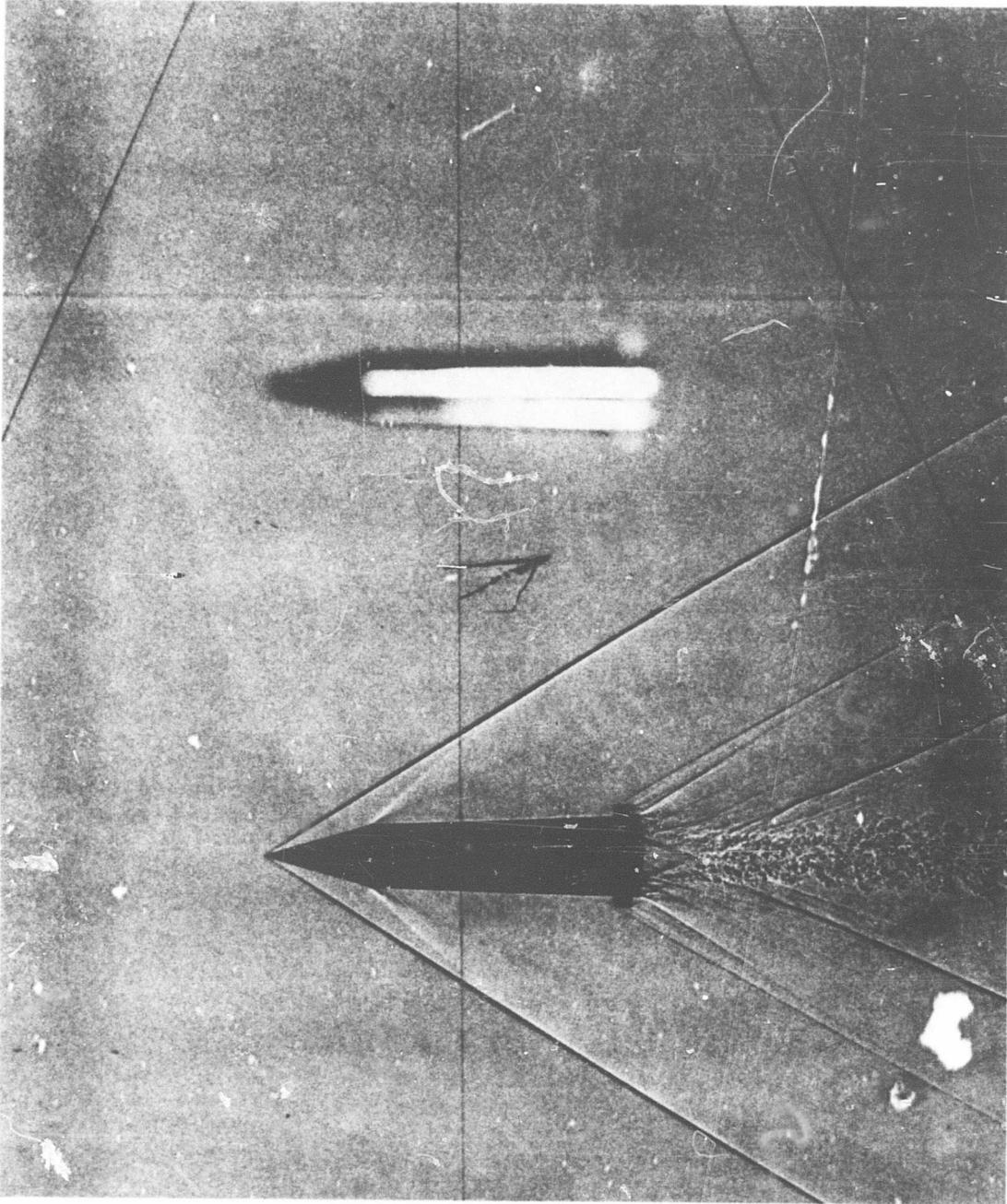


FIGURE 15 SHADOWGRAPH $M \approx 2.16$

CONFIDENTIAL

CONFIDENTIAL

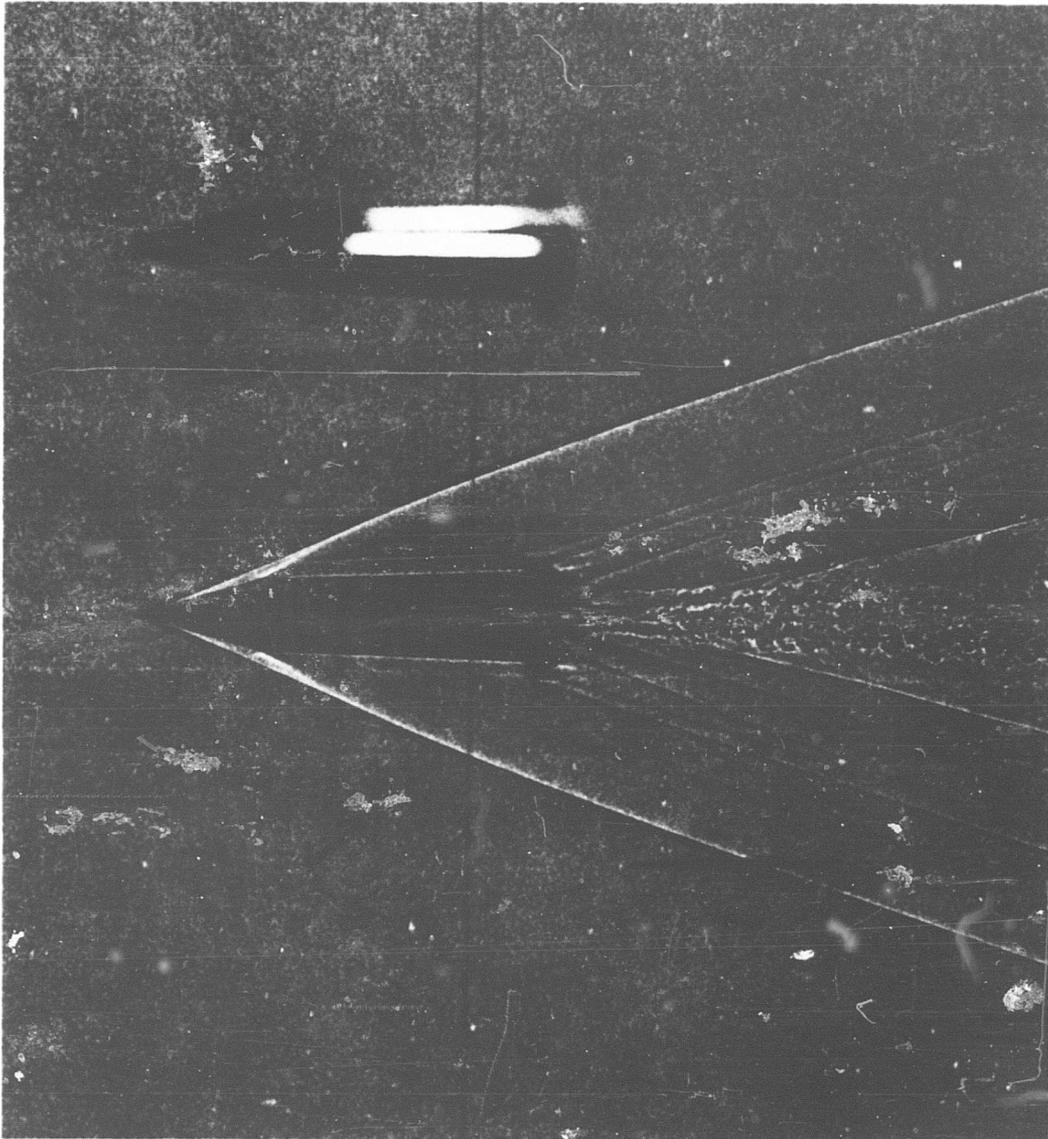


FIGURE 16 SHADOWGRAPH $M \approx 3.45$

PAGE

28

BLANK

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	Chief of Ordnance Department of the Army Washington 25, D. C. Attn: ORDTB - Bal Sec ORDTU	1	Commanding Officer and Director David W. Taylor Model Basin Washington 7, D. C. Attn: Aerodynamics Lab.
10	British Joint Services Mission 1800 K Street, N. W. Washington 6, D. C. Attn: Mr. John Izzard, Reports Officer	1	Commander Naval Air Development Center Johnsville, Pennsylvania
4	Canadian Army Staff 2450 Massachusetts Ave., N. W. 3 Washington 8, D. C.	1	Commanding Officer Naval Air Rocket Test Station Dover, New Jersey
3	Chief, Bureau of Ordnance Department of the Navy Washington 25, D. C. Attn: ReO	3	Commander Naval Ordnance Test Station China Lake, California Attn: Technical Library Aeroballistics Lab. Code 5034
2	Commander Naval Proving Ground Dahlgren, Virginia	4	Commander Air Research and Development Center P. O. Box 1395 Baltimore 3, Maryland Attn: Deputy for Development
2	Commander Naval Ordnance Laboratory White Oak Silver Spring, Maryland Attn: Technical Library	1	Commander Air Force Armament Center Eglin Air Force Base, Florida Attn: ACOT
1	Superintendent Naval Postgraduate School Monterey, California	1	Commander Arnold Engineering Development Center Tullahoma, Tennessee Attn: Deputy Chief of Staff, R&D
2	Commander Naval Air Missile Test Center Point Mugu, California		

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
10	Director Armed Services Technical Information Agency Document Service Center Knott Building Dayton 2, Ohio Attn: DSC - SD	1	Director, JPL Ord Corps Installation 4800 Oak Grove Drive Department of the Army Pasadena, California Attn: Mr. Irl E. Newlan, Reports Group
2	U. S. Atomic Energy Commission Sandia Corporation P. O. Box 5900 Albuquerque, New Mexico	6	Commanding General Redstone Arsenal Huntsville, Alabama Attn: Technical Library T. G. Reed, ABMA
1	Director National Advisory Committee for Aeronautics 1512 H Street, N. W. Washington 25, D. C.	3	Commanding Officer Picatinny Arsenal Dover, New Jersey Attn: Samuel Feltman Ammunition Lab.
1	Director National Advisory Committee for Aeronautics Ames Laboratory Moffett Field, California Attn: Dr. A. C. Charters Mr. H. J. Allen	1	Commanding General Frankford Arsenal Philadelphia 37, Pennsylvania Attn: Reports Group
		1	Commanding Officer Chemical Corps Chemical and Radiological Lab. Army Chemical Center, Maryland
3	Director National Advisory Committee for Aeronautics Langley Memorial Aeronautical Laboratory Langley Field, Virginia Attn: Mr. J. Bird Mr. C. E. Brown Dr. Adolf Busemann	1	Commanding Officer Diamond Ordnance Fuze Laboratories Washington 25, D. C. Attn: ORDTL - 06.33
		1	The Johns Hopkins University Operations Research Office 7100 Connecticut Avenue Chevy Chase, Maryland Washington 15, D. C. Attn: Document Control Office
1	Director National Advisory Committee for Aeronautics Lewis Flight Propulsion Lab. Cleveland Airport Cleveland, Ohio Attn: F. K. Moore		

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
2	Armour Research Foundation Illinois Institute of Technology Technology Center Chicago 16, Illinois Attn: Mr. W. Casier Dr. A. Wundheiler THRU: Commanding Officer Chicago Ordnance District 209 W. Jackson Blvd. Chicago, Illinois	1	CONVAIR Division of General Dynamics Corporation Ordnance Aerophysics Lab. Daingerfield, Texas Attn: Mr. J. E. Arnold THRU: Bureau of Ordnance Representative Ordnance Aerophysics Laboratory Daingerfield, Texas
2	Applied Physics Laboratory 8621 Georgia Avenue Silver Spring, Maryland Attn: Mr. George L. Seielstad THRU: Naval Inspector of Ordnance Applied Physics Lab. 9621 Georgia Avenue Silver Spring, Maryland	1	General Electric Company Missile and Ordnance Systems Department 3198 Chestnut Street Philadelphia, Pennsylvania Attn: A. M. Smith THRU: Commanding Officer Philadelphia Ordnance District 128 N. Broad Street Philadelphia 2, Pa. Attn: Mr. L. I. Chasen
1	Aerophysics Development Corp. P. O. Box 657 Pacific Palisades, California THRU: Commanding Officer Los Angeles Ordnance District 55 South Grand Avenue Pasadena 1, California	1	M. W. Kellogg Company Foot of Danforth Avenue Jersey City 3, New Jersey Attn: Miss E. M. Hedley THRU: Inspector of Naval Material Naval Industrial Reserve Shipyard Building 24, Port Newark Newark 5, New Jersey
1	Cornell Aeronautical Lab., Inc. 4455 Genesee Street Buffalo 5, New York Attn: Miss Elma T. Evans, Librarian THRU: Bureau of Aeronautics Representative P. O. Box 235 Buffalo 21, New York Attn: Commander Bolles	1	Ramo-Wooldridge Corporation 5730 Arbor Vitae Atrreet P. O. Box 45067 Airport Station Los Angeles 45, California THRU: Los Angeles Air Procurement District 1206 S. Maple Avenue Los Angeles 15, Calif.

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Research and Advanced Development Division AVCO Manufacturing Corp. 20 South Union Street Lawrence, Massachusetts Attn: Mr. W. Stevenson THRU: Boston Air Procurement District Boston Army Terminal Boston 10, Massachusetts	1	United Aircraft Corporation Research Department East Hartford 8, Connecticut Attn: Mr. C. H. King THRU: Bureau of Aeronautics Representative Pratt & Whitney Aircraft United Aircraft Corp. East Hartford 8, Conn.
1	Technical Documents Service Willow Run Laboratories University of Michigan Willow Run Airport Ypsilanti, Michigan Attn: Mr. J. E. Corey THRU: Commander Central Air Procurement District West Warren & Lonyo Ave. Detroit 32, Michigan	1	Wright Aeronautical Division Curtiss-Wright Corporation Wood-Ridge, New Jersey Attn: Sales Dept. (Government) THRU: Air Force Plant Representative Wright Aeronautical Division Wood-Ridge, New Jersey
1	University of So. California Engineering Center Los Angeles 7, California Attn: Mr. H. R. Saffell, Director THRU: Bureau of Aeronautics Representative Aerojet Engineering Corporation 6352 North Irwindale Avenue Azusa, California	1	Professor George Carrier Division of Applied Sciences Harvard University Cambridge 38, Massachusetts Professor Clark B. Milliken Guggenheim Aeronautical Lab. California Institute of Technology Pasadena 4, California Dr. A. E. Puckett Hughes Aircraft Company Culver City, California Dr. L. H. Thomas Watson Scientific Computing Laboratory 612 West 116th Street New York 27, New York

DISTRIBUTION LIST

No. of
Copies

Organization

1

Assistant Secretary of Defense (R&E)
The Pentagon
Washington 25, D. C.
Attn: Director, Guided Missiles

2

Chief of Staff
Department of the Army
Washington 25, D. C.
Attn: Director, Special Weapons
Army Ballistic Missile Committee

CONFIDENTIAL

AD 152954

Armed Services Technical Information Agency

**ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA**

**FOR
MICRO-CARD
CONTROL ONLY**

1 OF 1

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

CONFIDENTIAL

UNCLASSIFIED

UNCLASSIFIED